A Scoping Review of Digital Gaming Research Involving Older Adults Aged 85 and Older

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A Scoping Review of Digital Gaming Research Involving Older Adults Aged 85 and Older

Hannah R. Marston, PhD1,2 Shannon Freeman, PhD3 Kristen A. Bishop, MSc4 and Christian L. Beech, MSc5

Abstract

Background: Interest in the use of digital game technologies by older adults is growing across disciplines from health and gerontology to computer science and game studies. The objective of this scoping review was to examine research evidence involving the oldest old (persons 85 years of age or greater) and digital game technology.

Materials and Methods: PubMed, CINHAL, and Scopus were searched, and 46 articles were included in this review.

Results: Results highlighted that 60 percent of articles were published in gerontological journals, whereas only 8.7 percent were published in computer science journals. No studies focused directly on the oldest old population. Few studies included sample sizes greater than 100 participants. Seven primary and 34 secondary themes were identified, of which Hardware Technology and Assessment were the most common.

Conclusions: Existing evidence demonstrates the paucity of studies engaging older adults 85 years of age and above regarding the use of digital gaming and highlights a new understudied cohort for further research focus. Recommendations for future research include intentional recruitment and proportionate representation of participants ≥ 85 years of age, large sample sizes, and explicit mention of specific numbers of participants ≥85 years of age, which are necessary to advance knowledge in this area. Integrating a rigorous and robust mixed-methods approach including theoretical perspectives would lend itself to further in-depth understanding and knowledge generation in this field.

Introduction

Globally, the population of adults 65 years of age and over is growing exponentially with a particular increase among the “oldest old” (adults ≥ 85 years of age). With increased life expectancy, the population 80–89 years of age has increased 13 percent, with a 26 percent increase in those 90 years of age and above.1 Simultaneously, there is also rising pressure to better meet and understand the healthcare and social care needs of older adults. Since the release of the Nintendo Wii™ console in 2006 (Kyoto, Japan), research interest exploring the health benefits of digital games (computer game or videogame) on the health and well-being of aging populations has increased.2 However, with the growing prevalence of the oldest old, later life now encompasses several distinct generations (e.g., younger Baby Boomers, older Baby Boomers, the Silent Generation), most of which this study contends are underrepresented in research literature.

Previous studies related to videogaming have found a paucity of robust evidence showing physical-based interactive computer games as effective despite some indicators.3 Research focusing on the application, feasibility, and effectiveness of virtual reality (VR) digital gaming systems to manage or improve the effects of physical and mental impairment and limitations in community settings found insufficient evidence to validate the feasibility and effectiveness of such an approach. Conversely, one of the limitations from these studies is the lack of physical recommendations as noted by these authors.3 For example, Miller et al.3 found that “evidence to date supporting the feasibility and effectiveness of VR/gaming systems undertaken for enabling physical activity in a home setting to address impairments, activity limitations and

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4Faculty of Health Sciences, Health and Rehabilitation Sciences, Western University, London, Ontario, Canada.
5Centre for Innovative Ageing, Swansea University, Swansea, Wales, United Kingdom.
participation in people aged over 45 years old is relatively weak with a high risk of bias in this emerging area, and, therefore, insufficient to provide sound recommendations for clinical practice” (p. 193).

Furthermore, Miller et al. proposed that future studies should use a more rigorous study design and data collection methods. This recommendation is based on findings of their review identifying several “feasibility issues and inconsistencies relating to: recruitment, retention, target and recorded dosage of exercises, adherence, training, assistance, safety, cost, acceptability and take-up of technologies” (p. 193) within the existing knowledge base.

The importance of identifying suitable game technologies to improve the health and well-being of older people has been highlighted in several reviews, and several areas requiring further exploration have been identified. These areas include the need for a physical, cognitive, and social classification system specifically aimed at games for health while considering the implementation of longitudinal studies to ascertain the effects of videogames on participants, and Bleakley et al. provided 15 recommendations that related to the exploration of technologies across the selection/inclusion criteria, methodology, intervention, comparison group, outcomes, and follow-up, while also proposing the recommendation of tailoring the respective study to the participants and considering participant safety, engagement/motivation, and enjoyment. Conversely, Hall et al. proposed future studies should consider “more robust and rigorous research designs are needed to increase validity and reliability of results” (p. 1). Although Miller et al. echoed the recommendation of Hall et al., they also proposed three key points, including “The current evidence for the effectiveness of home-based VR/gaming for improving health-related domains in older adults is relatively weak with a high risk of bias and therefore insufficient to provide sound recommendations for clinical practice,strong retention and adherence with exercise, and the need for assistance, training and monitoring to ensure safety was identified and future studies should not only address the effectiveness of VR/gaming exercise programs for particular older populations, but also the feasibility issues specific to the implementation in a home environment using more rigorous research designs” (p. 194).

As life expectancy continues to increase, new and innovative research is needed to explore digital game use by the oldest old. To date, the state of evidence surrounding the effects of digital gaming on the oldest old remains unclear, and to the authors’ best knowledge, this review is the first attempt to investigate the breadth of research focusing on digital game use that included the oldest old and digital gaming technology. The five-stage Scoping Review framework by Arksey and O’Malley was selected to “map relevant literature in the field” (p. 4) and to identify gaps and inconsistencies in the knowledge base. These stages included (1) identification of the research question, (2) identification of relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results. Finally, a qualitative content analysis of existing literature was completed to identify core thematic dimensions through systematic coding and identification of patterns and themes. This approach was selected for its value in synthesizing data when research on a particular topic is limited and for how its purpose aligns nicely with the outcomes of a scoping review: to explore the breadth and depth of a topic while drawing conclusions about the overall state of research activity and identifying gaps and inconsistencies within the data.

Search strategy (identification of relevant studies)

The electronic databases PubMed, SCOPUS, and CINAHL were searched for articles published before January 1, 2014. Search terminology prioritized two search criteria: the oldest old and digital gaming (videogames). Individual search strategies were designed for each database (Table 1), and articles were exported and managed in the referencing software program RefWorks.

Study selection

The authors reviewed each article to determine eligibility based on inclusion and exclusion criteria. Inclusion criteria

Table 1. The Databases and Search Terms Used

<table>
<thead>
<tr>
<th>Database</th>
<th>MESH/search term</th>
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<tbody>
<tr>
<td>CINAHL</td>
<td>“video game*” OR (“virtual reality” AND game*) OR “game console*” OR “digital game*” OR Wii OR Nintendo OR Xbox OR Kinect OR “computer game*” OR cywee [in “Select a Field (optional)”] AND “in old age” OR aged OR aging OR “older people” OR “older adult*” OR elder* [in “Select a Field (optional)”]</td>
</tr>
<tr>
<td>SCOPUS</td>
<td>(TITLE-ABS-KEY(“video games” OR “gaming, experimental” OR “Wii” OR “Xbox” OR “Nintendo” OR “computer games” OR “digital games” OR “digital gaming” OR “game console”)) AND TITL ABS KEY(“aged, 80 and over” OR “oldest old” OR “centenarian” OR “nonagenarian” OR “octogenarian” OR “aged” OR “elderly” OR “older adult”))</td>
</tr>
</tbody>
</table>

MESH, medical subject heading.
were as follows: (a) the study included one or more participants or reported a mean participant age of 85 years or older; (b) the article examined videogame technology; (c) the study examined participant physiological and/or psychological health; (d) the study was published in the English language; and (e) the article was available through PubMed, CINAHL, or Scopus. Studies that did not report original results (e.g., commentaries, study protocols, letters to the editor) were excluded. Abstracts and full texts were retrieved to determine if they met the inclusion/exclusion criteria. Database searching identified 933 articles (Fig. 1). After duplicates were removed, 697 articles were screened for inclusion. Forty-six articles met the inclusion/exclusion criteria and were included in this scoping review.

Analysis (charting, summarizing, and collating the data)

Microsoft Excel® (Redmond, WA) was used to extract, categorize, and organize the data and themes. Primary and secondary themes and descriptive information were recorded for each article. The thematic analysis, undertaken independently by two of the four authors, first examined, pinpointed, and recorded themes across the articles, resulting in a series of highlighted categories. The themes of all included articles (n = 46) were independently reviewed by two raters who are also authors, and any discrepancies were then explored through consultation and resolved through detailed discussion. Through a six-phase process involving data familiarization, code generation, themes code summary and discussions, review of themes, defining and naming of themes, and synthesis of the results, the authors came to the consensus about themes. Seven primary themes emerged, and theme descriptions can be found in Table 2.

Results

Table 3 provides a detailed overview of included articles (n = 46). With the exception of that by Weisman, all studies were published between 2008 and 2013. The majority of studies (91.1 percent) were published in or after 2010, with 32.1 percent published in 2012 and 26.8 percent in 2013. Two-thirds of the articles (67.4 percent; n = 28) were published in 23 different aging- and health-focused journals, whereas 8.7 percent of articles were published in three different computer science–focused journals. Articles published in computer science–related journals were all published since 2012, of which 50.0 percent were published in 2013. The remaining 15 articles were published as conference proceedings (26.1 percent) and book chapters (4.4 percent). Multiple publications in the same journal including videogame use and the oldest old were rare. No journal was found to have published more than three articles including this demographic and subject area.

Sample sizes in these studies were often low (Table 3). The majority used sample sizes less than 50 (78.3 percent; n = 36), of which 3 were case studies with a sample size of one. In contrast, 6.5 percent of studies used a sample population greater than 100 (n = 3). No articles explicitly articulated an intention to study the oldest old population in relation to digital gaming technology use.

There were 7 primary themes (Table 4) and 34 secondary themes. Articles addressed an average of 5.8 primary themes (range, 4–7). Eight articles (17.4 percent) addressed all primary themes. All articles made reference to the Assessment and Technology Hardware themes. The majority of articles referenced the Environment (89.1 percent), Technology Software (89.1 percent), and Game Technology (80.4 percent) themes. Less commonly mentioned themes were Physiological Health (71.4 percent) and Psychological Health (50.0 percent).

Great diversity was evident among the distribution of articles reporting secondary themes. Articles addressed on average 10.3 secondary themes. In the assessment theme, 52.2 percent of articles addressed three or more secondary themes. Clinical assessments, such as the Victoria Stroop Test or the Berg Balance Scale, and activities of daily living were most commonly reported (73.9 percent), followed by discussion of anthropometric characteristics (60.9 percent). Few studies included Technology Validation (13.0 percent). More than two-thirds addressed one Hardware Technology secondary theme (69.6 percent), whereas only 28.3 percent addressed two, and 2.2 percent addressed three. No articles addressed four or more secondary Hardware Technology themes. Of specified videogame Hardware Technology secondary themes, more than half of the articles addressed the Nintendo console (58.7 percent), followed by the Xbox® Kinect® console (Microsoft) (13.0 percent) and Sony (Tokyo, Japan) console (4.4 percent). Hardware Technology utilization for mixed commercial purposes was addressed by 39.1 percent, whereas 17.4 percent addressed purpose-built devices.

Retirement communities (47.8 percent) and community-based settings (37.0 percent) were more commonly discussed Environment secondary themes, in contrast to institutional settings (e.g., hospitals, long-term care facilities) (17.9 percent).
Of the Software Technology secondary themes, the commercial theme was reported double the rate of the purpose-built/modified (technology that has been adapted or modified to conduct a certain task for a pathology) theme (63.0 percent versus 26.1 percent). No articles simultaneously addressed both Software Technology secondary themes.

Among the nine Game Technology secondary themes, articles were more likely to report one or two secondary themes (21.7 percent and 37.0 percent, respectively). Few articles addressed four to seven (13.0 percent), and no articles addressed more than seven Game Technology secondary themes.

Nearly one-third of articles addressed psychological benefits (32.6 percent), feasibility/efficacy (30.4 percent), physiological benefits (26.9 percent), and usability (23.9 percent).

As specified in the inclusion criteria, all articles must have addressed either the Physiological Health or Psychological Health primary theme. It is interesting that these were the two least commonly reported themes, with less than three-quarters reporting a Physiological Health theme (71.3 percent; \(n = 33\)) and half reporting a Psychological Health theme (50.0 percent; \(n = 23\)). For Psychological Health, the sub-themes of balance (47.8 percent), exercise (30.4 percent), and falls (28.3 percent) were much more common than articles that addressed rehabilitation (13.0 percent). For Psychological Health, cognition (29.3 percent) and quality of life (23.9 percent) were more common, in contrast to emotional well-being (19.6 percent) and mental health (13.0 percent).

**Discussion**

The majority of studies did not integrate the oldest old as a meaningful proportion of the sample, despite the increasing
<table>
<thead>
<tr>
<th>Reference (year)</th>
<th>Journal</th>
<th>Study design</th>
<th>Sample description</th>
<th>Sample size(s) (n)</th>
<th>Age (years) description</th>
<th>Percentage female</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agmon et al.11</td>
<td>Journal of Geriatrics Physical Therapy</td>
<td>Pilot study, quasi-experimental single group pre–post</td>
<td>Continuing care retirement communities</td>
<td>7</td>
<td>Mean = 84 Range = 78–92</td>
<td>57.1 percent</td>
<td>“Use of Wii Fit for limited supervised balance training in the home was safe and feasible for a selected sample of older adults” (p. 161)</td>
</tr>
<tr>
<td>Allaire et al.47 (2013)</td>
<td>Computers in Human Behavior</td>
<td>Pretest–posttest treatment control group design</td>
<td>Independently living older adults, senior centers, religious centers, and senior living apartments</td>
<td>140</td>
<td>Mean = 77.5 Range = 63–92</td>
<td>70.0 percent</td>
<td>“Differences among the groups were found for well-being, negative affect, social functioning, and depression with Regular and Occasional Gamers performing better, on average, than Non-gaming older adults. Findings suggest that playing may serve as a positive activity associated with successful aging” (p. 1302)</td>
</tr>
<tr>
<td>Anderson-Hanley et al.12 (2011)</td>
<td>Clinical Interventions in Aging</td>
<td>Pilot</td>
<td>Retirement communities</td>
<td>14</td>
<td>Mean = 80.7 for Sample 1, 75.6 for Sample 2 Range = 60–99</td>
<td>92.8 percent</td>
<td>“Virtual social facilitation increased exercise effort among more competitive exercisers. Exercise programs that match competitiveness may maximize exercise effort” (p. 275)</td>
</tr>
<tr>
<td>Anderson-Hanley et al.79 (2012)</td>
<td>American Journal of Preventive Medicine</td>
<td>Multisite cluster randomized clinical trial</td>
<td>Retirement communities</td>
<td>79</td>
<td>Mean = 75.7 for Sample 1 (cybercycle), 81.6 for Sample 2 (bike) Range = 58–99</td>
<td>75.0 Range = 67–85</td>
<td>“Cybercycling older adults achieved better cognitive function than traditional exercisers, for the same effort, suggesting that simultaneous cognitive and physical exercise has greater potential for preventing cognitive decline” (p. 109)</td>
</tr>
<tr>
<td>Bainbridge et al.13 (2011)</td>
<td>Physical &amp; Occupational Therapy in Geriatrics</td>
<td>Prospective, cross-sectional pilot</td>
<td>Community-dwelling older adults</td>
<td>8</td>
<td>Mean = 75.0 Range = 67–87 n 85+ = 2</td>
<td>87.5 percent</td>
<td>“[…] findings suggest that an intervention program including the Wii fit may be an effective rehabilitation option for older adults with perceived balance deficits” (p. 126)</td>
</tr>
<tr>
<td>Belcior et al.49 (2013)</td>
<td>Computers in Human Behavior</td>
<td>Feasibility/pilot pretest–posttest</td>
<td>Community surrounding University of Florida</td>
<td>58</td>
<td>Mean = 74.5 Range = 65–91</td>
<td>51.7 percent</td>
<td>“There was a lack of difference between the two game conditions, differing from findings with younger adults” (p. 1318)</td>
</tr>
<tr>
<td>Bieryla and Dold14 (2013)</td>
<td>Clinical Interventions in Aging</td>
<td>Pretest–posttest experimental</td>
<td>Senior living community</td>
<td>12</td>
<td>Mean = 81.5 Range = 70–92</td>
<td>83.3 percent</td>
<td>“Balance training with Nintendo’s Wii Fit may be a novel way for older adults to improve balance as measured by the BBS” (p. 775)</td>
</tr>
<tr>
<td>Boulay et al.15 (2011)</td>
<td>Technology and Health Care</td>
<td>Pilot usability</td>
<td>Institutionalized patients at LUSAGE Living Lab in Paris</td>
<td>7</td>
<td>Mean = 88.5 Range = 77–94 n 85+ = 6</td>
<td>57.1 percent</td>
<td>“[…] overall very satisfied with the game and expressed a desire to repeat the experience: MINWii fosters positive interaction with the caregivers and elicits powerful reminiscence with even the most severely impaired patients” (p. 1)</td>
</tr>
<tr>
<td>Celinder and Peoples46 (2012)</td>
<td>Scandinavian Journal of Occupational Therapy</td>
<td>Qualitative</td>
<td>Hospital</td>
<td>9</td>
<td>Mean = 68.2 Range = 51–95 n 85+ = 1</td>
<td>33.3 percent</td>
<td>“Stroke patients in hospital settings may experience Wii Sports as a beneficial and challenging occupation for both rehabilitation and leisure. Incorporation of Wii Sports into conventional occupational therapy services may benefit patient rehabilitation directly or provide motivation for alternative leisure activities” (p. 457)</td>
</tr>
<tr>
<td>Chao et al.17 (2013)</td>
<td>Geriatric Nursing</td>
<td>Single-group, pre–post test</td>
<td>Assisted living residence</td>
<td>7</td>
<td>Mean = 86.0 Range = 80–94</td>
<td>71.4 percent</td>
<td>“The use of Wii exergames was acceptable, safe, and potentially effective approach to promote physical activity in older adults. Findings provide support for the applications of integrating self-efficacy theory into exergames as a mechanism to encourage older adults to engage in exercise” (p. 377)</td>
</tr>
<tr>
<td>Reference (year)</td>
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<td>Study design</td>
<td>Sample description</td>
<td>Sample size(s) (n)</td>
<td>Age (years) description</td>
<td>Percentage female</td>
<td>Main findings</td>
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<tr>
<td>Chen et al. (^{50}) (2012)</td>
<td>IEEE</td>
<td>Quasi-experimental</td>
<td>Institutionalized older adults</td>
<td>61</td>
<td>Mean = 78.6 for Sample 1, 79.5 for Sample 2, Range = 65–92</td>
<td>70.5 percent</td>
<td>“[…] somatosensory video games had a great potential to be used as a health promotion tool for the elderly with disabilities” (p. 258)</td>
</tr>
<tr>
<td>Clark and Kraemer (^{18}) (2009)</td>
<td>Journal of Geriatric Physical Therapy</td>
<td>Case report</td>
<td>Nursing home</td>
<td>89</td>
<td>100 percent</td>
<td></td>
<td>“Physical therapy intervention, using the Nintendo Wii bowling simulation, may have decreased fall risk for this individual” (p. 174)</td>
</tr>
<tr>
<td>Cornejo et al. (^{19}) (2012)</td>
<td>Conference proceedings for International Conference on Pervasive Computing Technologies for Healthcare</td>
<td>Design</td>
<td>Family interaction, community dwelling</td>
<td>1</td>
<td>86</td>
<td>100 percent</td>
<td>“The system maintained the older adult engaged with her exercises while offering new opportunities for online and offline social encounters. […] the use of natural interfaces and family memorabilia facilitated the adoption of the game and catalyzed family social encounters” (p. 215)</td>
</tr>
<tr>
<td>Dougherty et al. (^{20}) (2010)</td>
<td>Missouri Medicine</td>
<td>Within-subject experimental</td>
<td>Local senior community center</td>
<td>9</td>
<td>Mean = 74.9, Range = 65–90, 85+ = 1</td>
<td>33.3 percent</td>
<td>“These improvement are postulated to be due to an increase in subjects’ core and lower extremity muscle strength and improve proprioception; a result of balance board usage” (p. 128)</td>
</tr>
<tr>
<td>Fachko et al. (^{21}) (2013)</td>
<td>Journal of Gerontological Nursing</td>
<td>Observational</td>
<td>Independently living</td>
<td>34</td>
<td>Mean = 81.0, Range = 69–91</td>
<td>70.6 percent</td>
<td>“[…] results suggest that Nintendo Wii Tennis EG technology represents an enjoyable, moderate intensity physical activity for healthy, older adults” (p. 43)</td>
</tr>
<tr>
<td>Franco et al. (^{22}) (2012)</td>
<td>Technology and Health Care</td>
<td>Randomized pre-post intervention</td>
<td>Community-dwelling seniors, independent living senior housing facility</td>
<td>32</td>
<td>Mean = 78.3, Range = 63–90</td>
<td>78.1 percent</td>
<td>“[…] the interventions failed to significantly increase balance, with an increase in intervention duration of Wii Fit or Matter of Balance balance may be improved. Although results were not significant this study adds to the growing body of evidence regarding the use of Wii Fit as a rehabilitation tool” (p. 95).</td>
</tr>
<tr>
<td>Gerling et al. (^{23}) (2015)</td>
<td>Proceedings of Graphics Interface</td>
<td>Evaluation</td>
<td>Not specified</td>
<td>33 (Sample 1, n = 16; Sample 2, n = 17)</td>
<td>Sample 1: mean = 23.9, range = 18–27; Sample 2: mean = 71.5, range = 62–86</td>
<td>60.6 percent</td>
<td>“[…] results show that older adults can apply motion-based game controls efficiently, and that they enjoy motion-based interaction” (abstract, paragraph 1)</td>
</tr>
<tr>
<td>Harley et al. (^{24}) (2010)</td>
<td>HCI in Work and Learning, Life and Leisure</td>
<td>Longitudinal</td>
<td>Communal housing setting, sheltered housing settings</td>
<td>30</td>
<td>Range = 60–94</td>
<td>Not specified</td>
<td>“[…] older players create a ‘sacred space’ around the Wii where they can learn new technical literacies, make new social connections with peers and take ownership of the communal spaces in which they live” (p. 156)</td>
</tr>
<tr>
<td>Jung et al. (^{25}) (2009)</td>
<td>Proceedings of the Sixth Australasian Conference on Interactive Entertainment</td>
<td>Longitudinal field experiment</td>
<td>Long-term care</td>
<td>45</td>
<td>Range = 56–92</td>
<td>Not specified</td>
<td>“Results showed that playing Wii games had a positive impact on the overall well-being of the elderly, compared to a control group that played traditional board games. Implications for future applications of Wii in interventions for the elderly are discussed” (p. 1)</td>
</tr>
<tr>
<td>Kahlbaugh et al. (^{26}) (2011)</td>
<td>Activities, Adaptation &amp; Aging</td>
<td>Randomized controlled trial</td>
<td>Independent living residential apartments</td>
<td>36</td>
<td>Mean = 82.0, Range = 50–94, 85+ = 18</td>
<td>88.6 percent</td>
<td>“The elderly playing Wii had lower loneliness and a pattern of greater positive mood compared to the television group. No differences in life satisfaction or physical activity were found, but loneliness predicted positive mood, and positive mood predicted physical activity” (p. 331)</td>
</tr>
<tr>
<td>Reference (year)</td>
<td>Journal</td>
<td>Study design</td>
<td>Study setting or context</td>
<td>Sample size(s) (n)</td>
<td>Age (years) description</td>
<td>Percentage female</td>
<td>Main findings</td>
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<tr>
<td>Keogh et al. 27 (2012)</td>
<td>Journal of Community Informatics</td>
<td>Quasi-experimental mixed-methods pilot</td>
<td>Nursing home</td>
<td>11</td>
<td>Mean = 81, n 85+ = 3</td>
<td>54.6 percent</td>
<td>&quot;[…] the results of our study suggest that the use of the NWS is feasible in the nursing home context and that the residents may experience some psychosocial benefits after only five weeks of a self-selected amount of NWS game play. This suggests that even short-term unstructured use of this technology may be of some benefit to some nursing home residents.&quot; (p. 10).</td>
</tr>
<tr>
<td>Keogh et al. 28 (2014)</td>
<td>Journal of Aging and Physical Activity</td>
<td>Mixed-methods, quasi-experimental pilot</td>
<td>Residential aged care centers</td>
<td>34</td>
<td>Mean = 83, Range = 68–99</td>
<td>88.2 percent</td>
<td>&quot;Analysis of the quotes underlying the three themes (Feeling Silly, Feeling Good; Having Fun; and Something to Look Forward to) suggested that intervention group participants developed a sense of empowerment and achievement after some initial reluctance and anxiousness. They felt that the games were fun and provided an avenue for greater socialization&quot; (p. 235)</td>
</tr>
<tr>
<td>Koslucher et al. 29 (2012)</td>
<td>Gait &amp; Posture</td>
<td>Experimental</td>
<td>University of Minnesota retirees volunteer list, community</td>
<td>10</td>
<td>Mean = 72.6, Range = 64–85</td>
<td>Not specified</td>
<td>&quot;The WBB is an inexpensive, reliable technology that can be used to evaluate subtle characteristics of body sway in large or widely dispersed samples&quot; (p. 605)</td>
</tr>
<tr>
<td>Laver et al. 30 (2011)</td>
<td>BMC Geriatrics</td>
<td>Discrete choice experiment</td>
<td>Geriatric rehabilitation hospital</td>
<td>21</td>
<td>Mean = 85.4</td>
<td>86.0 percent</td>
<td>&quot;The usefulness of the Wii Fit as a therapy tool with hospitalised older people is limited not only by the small proportion of older people who are able to use it, but by older people’s preferences for traditional approaches to therapy&quot; (p. 1)</td>
</tr>
<tr>
<td>Liu et al. 31 (2012)</td>
<td>Fourth IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning</td>
<td>Cross-sectional</td>
<td>Community</td>
<td>111</td>
<td>Mean = 63.8, Range = 55–90</td>
<td>0.0 percent</td>
<td>&quot;[…] using Wii video games to promote elderly’s health is a potential valuable approach to understand their physical fitness, to motivate them to exercise and to understand their HRQOL.&quot; (p. 207)</td>
</tr>
<tr>
<td>Löckenhoff et al. 32 (2013)</td>
<td>The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences</td>
<td>Quasi-experimental print and online ads</td>
<td>Community through print and online ads</td>
<td>80 (total) 40 (Sample 1) 40 (Sample 2)</td>
<td>Sample 1: mean = 28.0, range = 22–39 Sample 2: mean = 71.4, range = 58–89</td>
<td>73 percent</td>
<td>&quot;Older adults were less likely than younger adults to respond to mild levels of social exclusion, but both age groups responded similarly to more pronounced exclusion. Within the older group, participants with lower cognitive functioning were less responsive to mild exclusion, but this effect did not reach significance in the younger group&quot; (p. 13)</td>
</tr>
<tr>
<td>Olvera-Chávez et al. 33 (2013)</td>
<td>Gerontotechnology</td>
<td>Cross-sectional</td>
<td>Community</td>
<td>20</td>
<td>Mean = 67.5, Range = 60–98</td>
<td>75.0 percent</td>
<td>&quot;The Wii pressure board has a good concordance with usual clinical assessment of balance in the elderly&quot; (p. 452)</td>
</tr>
<tr>
<td>Pichierri et al. 34 (2012)</td>
<td>BMC Geriatrics</td>
<td>Prospective randomized controlled trial</td>
<td>Swiss hostels for the aged</td>
<td>31</td>
<td>Mean = 86.2</td>
<td>58.1 percent</td>
<td>&quot;These findings suggest that in older adults a cognitive-motor intervention may result in more improved gait under dual task conditions in comparison to a traditional strength and balance exercise program&quot; (p. 1)</td>
</tr>
</tbody>
</table>

(continued)
Table 3. (Continued)

<table>
<thead>
<tr>
<th>Reference (year)</th>
<th>Journal</th>
<th>Study design</th>
<th>Study setting or context</th>
<th>Sample size(s) (n)</th>
<th>Age (years) description</th>
<th>Percentage female</th>
<th>Main findings</th>
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<tbody>
<tr>
<td>Pichierri et al.33 (2012)</td>
<td>Clinical Interventions in Aging</td>
<td>Prospective randomized controlled trial, pilot study</td>
<td>Care homes</td>
<td>25</td>
<td>Sample 1 (Intervention): mean = 83.6 Sample 2 (Control): mean = 86.2</td>
<td>60.0 percent</td>
<td>“A cognitive-motor intervention based on strength and balance exercises with additional dance video gaming is able to improve voluntary step execution under both single and dual task conditions in older adults” (p. 175).</td>
</tr>
<tr>
<td>Pompeu et al.34 (2012)</td>
<td>Physiotherapy</td>
<td>Parallel, prospective, single-blind, randomized clinical trial</td>
<td>Parkinson’s Association</td>
<td>32</td>
<td>Mean = 67.4 Range = 60–85</td>
<td>46.8 percent</td>
<td>“Patients with Parkinson’s disease showed improved performance in activities of daily living after 14 sessions of balance training, with no additional advantages associated with the Wii-based motor and cognitive training” (p. 196).</td>
</tr>
<tr>
<td>Reichlin et al.35 (2011)</td>
<td>Journal of Medical Internet Research</td>
<td>Mixed-methods</td>
<td>Hospital</td>
<td>13</td>
<td>Range = 45–85</td>
<td>0.0 percent</td>
<td>“Serious games are a promising approach to health education and decision support for older men. Participants were receptive to the idea of a serious game as a decision aid in localized prostate cancer. However, usability issues are a major concern for this demographic, as is clarity and transparency of data sources” (paragraph 4).</td>
</tr>
<tr>
<td>Schoene et al.33 (2014)</td>
<td>Age and Ageing</td>
<td>Cross-sectional study</td>
<td>Independently living cognitively intact older adults, retirement residences</td>
<td>103</td>
<td>Mean = 79.5 Range = 70–93</td>
<td>Not specified</td>
<td>“[…] the SST a low-cost video game device is feasible for older people to undertake. The SST was able to distinguish fallers from non-fallers, providing a novel way to explore cognitive mechanisms for fall-risk in older people” (p. 1).</td>
</tr>
<tr>
<td>Schoene et al.36 (2011)</td>
<td>Archives of Physical Medicine and Rehabilitation</td>
<td>Randomized order, crossover comparison</td>
<td>Balance laboratory, medical research institute, and retirement village</td>
<td>47</td>
<td>Mean = 78.9 Range = 65–90</td>
<td>55.0 percent</td>
<td>“The new dance mat device is a valid and reliable tool for assessing stepping ability and fall risk in older community-dwelling people. Because it is highly portable, it can be used in clinic settings and the homes of older people as both an assessment and training device” (p. 947).</td>
</tr>
<tr>
<td>Sirkka et al.37 (2011)</td>
<td>Europe PubMed Central</td>
<td>Preliminary experiment</td>
<td>Assisted living environments</td>
<td>34</td>
<td>Mean = 85.9 Range = 70–98</td>
<td>50.0 percent</td>
<td>“The overall experiences of mobile controlled game described in this paper appeared to be a successful experiment also proving that the elderly are not as reluctant to use technical devices or playing virtual games as often thought. The game was reckoned very motivating, interesting, and entertaining both by the aged and the staff” (p. 289).</td>
</tr>
<tr>
<td>Smeddinck et al.38 (2013)</td>
<td>ACM SIGACCESS</td>
<td>Comparative study within-subjects design</td>
<td>Weekly community groups of older adults</td>
<td>15</td>
<td>Mean = 73.6 Range = 61–85</td>
<td>86.7 percent</td>
<td>“[…] while older adults do have preferences in terms of visual complexity of video games, notable effects were only measurable following drastic variations. […] perceived exertion shifts depending on the degree of visual complexity” (p. 289).</td>
</tr>
<tr>
<td>Stone and Skubic39 (2012)</td>
<td>Conference Proceedings for 2012 6th International Conference on Pervasive Computing Technologies for Healthcare</td>
<td>Quasi-experimental</td>
<td>Independent living facility</td>
<td>7</td>
<td>Range = 75–95</td>
<td>42.9 percent</td>
<td>“[…] a single Kinect sensor and computer have been deployed in five apartments, two of which contain multiple residents, in an independent living facility for older adults” (p. 183).</td>
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</table>

(continued)
Table 3. (Continued)

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<tr>
<td>Stone and Skubic40</td>
<td>IEEE Transactions on Biomedical Engineering</td>
<td>Probabilistic methodology for generating gait estimates</td>
<td>Independent living facility</td>
<td>15</td>
<td>Range=67–97</td>
<td>60.0 percent</td>
<td>“A probabilistic methodology for generating automated gait estimates over time for the residents of the apartments from the Kinect data is described, along with results from the apartments as compared to two of the traditionally measured fall risk assessment tools” (p. 2925)</td>
</tr>
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<td>Sugarman et al.41</td>
<td>IEEE</td>
<td>Feasibility pilot study</td>
<td>Hospital</td>
<td>1</td>
<td>Age=86</td>
<td>100 percent</td>
<td>“[…] the Wii Fit gaming system has the potential to be used in clinical settings in order to improve balance” (p. 111)</td>
</tr>
<tr>
<td>Torres42 (2008)</td>
<td>ZON Digital Games 2008</td>
<td>Pre–post assessment</td>
<td>Senior homes</td>
<td>43</td>
<td>Mean=78.3 Range=65–93</td>
<td>76.7 percent</td>
<td>“[…] results show that the use of videogames leads to the improvement of cognitive functioning and to the maintenance of the self-concept and the quality of life of elderly people” (p. 21).</td>
</tr>
<tr>
<td>Tsai et al.55 (2012)</td>
<td>Computer Aided Design &amp; Applications</td>
<td>Quasi-experimental</td>
<td>Elderly community</td>
<td>52</td>
<td>Mean=79.0 Range=64–91 n 85+=10</td>
<td>67.3 percent</td>
<td>“Our findings indicated that all proposed hypotheses had a positive and significant impact on the intention of older people to interact with Sharetouch. Unlike the computer-based system, Sharetouch is created as a user-friendly interface system. Sharetouch can enrich the users’ social network experiences through its hardware and software architectures” (p. 1364)</td>
</tr>
<tr>
<td>Weisman50 (1983)</td>
<td>The Gerontologist</td>
<td>Quasi-experimental</td>
<td>Institutionalized elderly</td>
<td>50</td>
<td>Mean=85.0</td>
<td>Not specified</td>
<td>“Moderate mental and physical impairments did not prevent 50 nursing home residents from participating in four computer games which were especially adapted for this population” (p. 361)</td>
</tr>
<tr>
<td>Weybright et al.43</td>
<td>Therapeutic Recreation Journal</td>
<td>Single-subject, multiple baseline ABAB design</td>
<td>Assisted living facility</td>
<td>2</td>
<td>Mean=89.5 Range=86–93</td>
<td>100 percent</td>
<td>“The low-impact activity of the Nintendo Wii™ bowling program may provide the appropriate amount of physical and mental challenge and stimulation for older adults with mild cognitive impairments” (p. 271)</td>
</tr>
<tr>
<td>Whitlock et al.54</td>
<td>Proceedings of the Human Factors and Ergonomics Society Annual Meeting</td>
<td>Cognitive Intervention study</td>
<td>Independent living facilities, assisted living facilities, and the community</td>
<td>56</td>
<td>Mean=79.8 Range=65–93</td>
<td>Not specified</td>
<td>“We examined video recordings and open-ended questionnaire responses of 56 older adults taking part in a video game-based cognitive intervention study. Usability findings and recommendations for inclusive video game design for older adults are discussed” (p. 187)</td>
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<tr>
<td>Williams et al.44</td>
<td>Occupational Therapy in Health Care</td>
<td>Pilot study, quasi-experimental, single group, pretest–posttest</td>
<td>Independent retirement communities or skilled nursing facilities</td>
<td>22</td>
<td>Mean=83.9 Range=74–94</td>
<td>81.8 percent</td>
<td>“[…] results of this study suggest the potential effectiveness of utilizing the Nintendo Wii as a therapeutic agent in occupational therapy practice” (p. 131)</td>
</tr>
<tr>
<td>Yamada et al.45</td>
<td>Geriatric Nursing</td>
<td>Quasi-experimental</td>
<td>Community-dwelling</td>
<td>45</td>
<td>Mean=81.3</td>
<td>100 percent</td>
<td>“[…] results suggest that game-based fall risk assessment using the Basic Step has a high generality and is useful in community-dwelling older adults” (p. 188)</td>
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<tr>
<td>Zavala-Ibarra and Favela46 (2012)</td>
<td>2012 Eighth International Conference on Intelligent Environments, IEEE</td>
<td>Evaluation study</td>
<td>Community center</td>
<td>11</td>
<td>Range=65–85</td>
<td>Not specified</td>
<td>“[…] a formative evaluation of the games with 5 older adults to assess ease of use and their interest in playing them. We compare the results of traditional measures of muscle strength using a clinical dynamometer with those obtained using the videogame” (p. 27)</td>
</tr>
</tbody>
</table>

EG, exergame; HRQOL, health-related quality of life; NWS, Nintendo “Wii Sports”; SST, Stroop Stepping Test; WBB, Wii Balance Board.
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<td>Agmon et al.11 (2011)</td>
<td>Balance</td>
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<td>Residential/retirement communities</td>
<td>Nintendo Wii</td>
<td>Commercial</td>
<td>Anthropometric, clinical, self-reporting, technology-assisted, qualitative</td>
<td>Usability, accessibility, subject preferences, feasibility/efficacy, psychological benefits, physiological benefits</td>
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<td>Bainbridge et al.13 (2011)</td>
<td>Balance</td>
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<td>Community-dwelling</td>
<td>Nintendo Wii</td>
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<tr>
<td>Belchior et al.49 (2013)</td>
<td>Cognition, attention</td>
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<td>Community-dwelling</td>
<td>Sony PlayStation, computer/mixed commercial</td>
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<td>Boulay et al.15 (2011)</td>
<td>Cognition</td>
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<td>Hospital/long-term care</td>
<td>Nintendo Wii, computer/mixed commercial</td>
<td>Self-reporting, technology-assisted, qualitative</td>
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<td>Celinder and Peoples16 (2012)</td>
<td>Rehabilitation</td>
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<tr>
<td>Chen et al.(^{50}) (2012)</td>
<td>Quality of life, emotional well-being</td>
<td>Hospital/long-term care</td>
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<td>Clark and Kraemer(^{18}) (2009)</td>
<td>Balance, falls</td>
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<td>Cornejo et al.(^{19}) (2012)</td>
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<td>Purpose-built, Kinect</td>
<td>Purpose-built</td>
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<td>Dougherty et al.(^{20}) (2010)</td>
<td>Balance, falls, exercise</td>
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<td>Fachko et al.(^{21}) (2013)</td>
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<td>Franco et al.(^{22}) (2012)</td>
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<tr>
<td>Gerling et al.(^{23}) (2013)</td>
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<td>Kinect, Sony PlayStation, Computer/mixed commercial</td>
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<td>Harley et al.(^{24}) (2010)</td>
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<td>Qualitative</td>
<td>Accessibility, psychological benefits</td>
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<td>Keogh et al.27 (2012)</td>
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<td>Laver et al.30 (2011)</td>
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<td>Löckenhoff et al.52 (2013)</td>
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<td>Self-reporting, qualitative</td>
<td>Usability, accessibility, design</td>
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<td>Williams et al. (2011)</td>
<td>Balance</td>
<td>Community-dwelling, residential/retirement communities</td>
<td>Nintendo Wii Commercial</td>
<td>Anthropometric, clinical</td>
<td>Psychological benefits, physiological benefits</td>
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<tr>
<td>Yamada et al. (2011)</td>
<td>Balance, falls</td>
<td>Cognition</td>
<td>Community-dwelling</td>
<td>Nintendo Wii Commercial</td>
<td>Anthropometric, clinical, technology-assisted, technology validation</td>
<td>Feasibility/efficacy, diagnostic tool</td>
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<tr>
<td>Zavala-Ibarra and Favela (2012)</td>
<td>Balance, falls</td>
<td>Public space</td>
<td>Nintendo Wii, Kinect</td>
<td>Commercial</td>
<td>Anthropometric, self-reporting</td>
<td>Usability, subject preferences, psychological benefits, subject perception, physiological benefits, design</td>
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global attention surrounding this rapidly growing population cohort. Most articles ($n = 35$) clearly identified the proportion of the sample size made up of the oldest old. To clarify sample proportions and enable our analysis, two authors contacted the respective authors seeking further clarification of the actual number of participants $\geq 85$ years of age when necessary. Consistent with previous reviews, this study highlights a substantial gap in the knowledge base and encourage further exploration into digital gaming use in those 85 years of age and greater. Future research is warranted using a representative sample of the oldest old cohort to facilitate greater understanding of cohort-specific needs and challenges to using and implementing videogaming technology.

For this scoping review, the decision not to limit articles based on a particular number of individuals $\geq 85$ years of age was made in order to demonstrate the meager way this population is integrated in this knowledge base. Our findings demonstrate that individuals in the oldest old age group are either minimally included or are excluded all together and rarely receive the primary focus as a sample group within the virtual gaming technology literature. Further research is needed that focuses primarily on the videogaming experience of adults in this age cohort in order to fully understand their specific rehabilitation and health needs.

It is possible that the number of studies including the oldest old is underrepresented as it was found many studies did not explicitly state the exact number of participants $\geq 85$ years of age. Although an age range was described, it is possible there is a publication bias or a failure of studies to report actual age range. Some studies only reported the age range with no mean or standard deviation; conversely, five studies reported the mean age but no age range or standard deviation. Albeit the authors were able to substantiate some aspect of the participants’ ages, the authors believe future studies should use clear measures to depict the exact number of participants $\geq 85$ years of age and aim to have a proportionate representation of older adults in studies. Recruitment of larger sample sizes is crucial to gain additional and in-depth knowledge of one’s experience in addition to measuring the attrition and adherence of training programs.

Seven of the 46 articles did not report the percentage of female participants included in the study, and two articles did not have any female participants in their sample. The remaining 37 articles all reported high percentages of female participants, thus being the majority of the gender split. The study setting/context varied widely across the 46 articles and was composed of retirement/independent communities, community dwelling, hospital/assisted living/residential/nursing home/long-term care/institutionalized or community center. The majority of the studies were primarily conducted across two different living environments (hospital/assisted living/residential/nursing home/long-term care/institutionalized) or retirement/independent living communities. Due to the nature of the age cohort, it is possible that many future studies will be required to recruit from hospital/assisted living/residential/nursing home/long-term care/institutionalized environments. However, if it is the aim of the academic community to utilize technology with the means of maintaining independence into old age, then recruitment from community dwelling/centers should be a primary focal point in future studies.

Various study designs have been conducted to explore this topic, including experimental, quasi-experimental, and non-experimental designs (Table 3). It is noticeable that experimental and quasi-experimental study designs were most prominent. Yet, there were also limited studies focusing on evaluation and using a qualitative or mixed-methods focus. Future studies should consider taking an observation, evaluation, and/or longitudinal/field experiment approach, which in turn would provide researchers and the community greater depth surrounding the feelings and experiences of the oldest old to support expanding current understanding of the utilization and deployment of the technology in a real-life setting. Additionally, taking into account the studies of Bleepley et al. and Miller et al. noted in the Introduction, by tailoring specific studies with robust methods and theory, it is possible that future studies will be able to provide a more substantial and robust validity and reliability of results for academics and clinicians wishing to use videogames for health and rehabilitation.

Based on the findings of this review, all articles referred to the Assessment and Technology Hardware themes, whereas a substantial number of articles covered the Environment, Technology Software, and Games Technology themes. Conversely, the primary themes of Physiological and Psychological Health were less common, which implies the primary aim of the studies may not have been physiological or psychologically related but more attuned to the technology, software, or environment itself, with a secondary focus of physiological and psychological health integrated. However, the physiological theme is prevalent across both gerontology and computer science journals, albeit gerontology is more prominent.

Based on the results of this study, research to date involving the oldest old and videogames has predominantly been published in gerontological journals and not in computer science journals. Since 2011, studies published in the computer science field were predominantly found in conference proceedings, resulting in limited access or knowledge for those accessing the gerontological knowledge base. The same can be noted when trying to access published work in gerontology journals from a computer science department. What this means is that these two fields have continued to emerge independently; however, a more pluralistic approach to videogaming technology in the oldest old may be a way forward to advance knowledge on the intersection of these two topics and a way to bridge the knowledge gap for both sides.

Opportunity exists for further research to conduct more extensive studies related to the impact of results and outcomes from studies included in this review with a representative study population of the oldest old and a direct focus on their use of videogame technology in regard to psychological impact on aging cohorts while still aiming to ascertain suitable solutions for physiological age-related impairments. This may enable study design and execution to better target this population and identify age-related characteristics and issues for consideration.

This article shows a positive incline toward understanding the use of videogame technology for health and aging populations. The 2006 release of the Nintendo Wii console has
promoted the use of digital game consoles for health benefits resulting in innovative research projects. The 2010 release of the Microsoft Kinect has also raised interest based on speech recognition and gesture interaction with the environment.

Four key points have been identified from the results of this scoping review. The increasing attention to videogame research including the older adult population in the past 5 years may coincide with recent advancements experienced in the videogaming industry and the positive public/health interest in interactive videogame technology such as the Nintendo Wii and Kinect consoles. The majority of articles used the Nintendo console ($n=27$), supporting previous findings showing positive benefits to well-being, quality of life, and cognitive performance and it being a low-cost, effective piece of technology for utilization of physical activity and balance.19–21 Furthermore, over one-third of articles used a mixed variation of purpose-built and commercial hardware. Researchers have also been quick to integrate newer videogame technology into studies; 10.7 percent of articles used the Kinect console despite the fact that the hardware was only released in 2010.

Based on user engagement within the environment, as well as expansion of gesture and speech recognition and in particular with the Xbox One, Kinect version 2.0, the software may be of increased benefit to the oldest old. Measuring heart rate and blood pressure through such platforms offers the possibility to hypothesize the presence of stress, depression, and mental and other physical conditions,56,57 which may be of great use to the older adults, including the oldest old, thus warranting their inclusion in research studies.

Themes relating to balance, falls, cognition, emotional well-being, and quality of life were prevalent; however, validation and reliability were lacking.13,48

We propose a series of recommendations to further enhance the work in this area and in regard to the recruitment and reporting of participants $\geq 85$ years of age: Integrating and executing a mixed-methods approach to data collection may be advantageous to gain an in-depth understanding of the role technology can play within the lives of oldest old from multiple perspectives. Using video recording to analyze observations, interviews, focus groups, and specific game data may produce greater knowledge. Further analyses could examine attitudes to technology, methods of learning technology, technology preferences, and usage. Furthermore, in-game experiences, performance, the effects of flow and immersion, player satisfaction and personality traits, usability, and accessibility experiences of study participants should also be considered. Future studies using the Nintendo or the Kinect consoles should consider executing validation and reliability testing of the technology. Prospective research is warranted to better understand cohort differences among the older adult population to form an initial baseline data for longitudinal research.

Conclusions

Although this review is timely in summarizing the breadth of studies that have recruited adults $\geq 85$ years of age for participation with videogames, several points have been highlighted based on the results and in conjunction with the proposed recommendations. This article highlights the necessity for primary research to be undertaken with individuals $\geq 85$ years of age based on the presence of low sample sizes, poor representation of study proportions, and the absence of studies that have included a meaningful proportion in their sample size and the sole focus is on the oldest old. The authors anticipate the proposed recommendations will improve the quality of data collection and to encourage interdisciplinary collaboration between the computer science and gerontology fields in order to encourage future studies focused on this cohort and provide greater understanding of technology use for an aging society.

Author Disclosure Statement

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